Electrical Measurements

Code: EPM1202

Lecture: 4 Tutorial: 2 Total: 6

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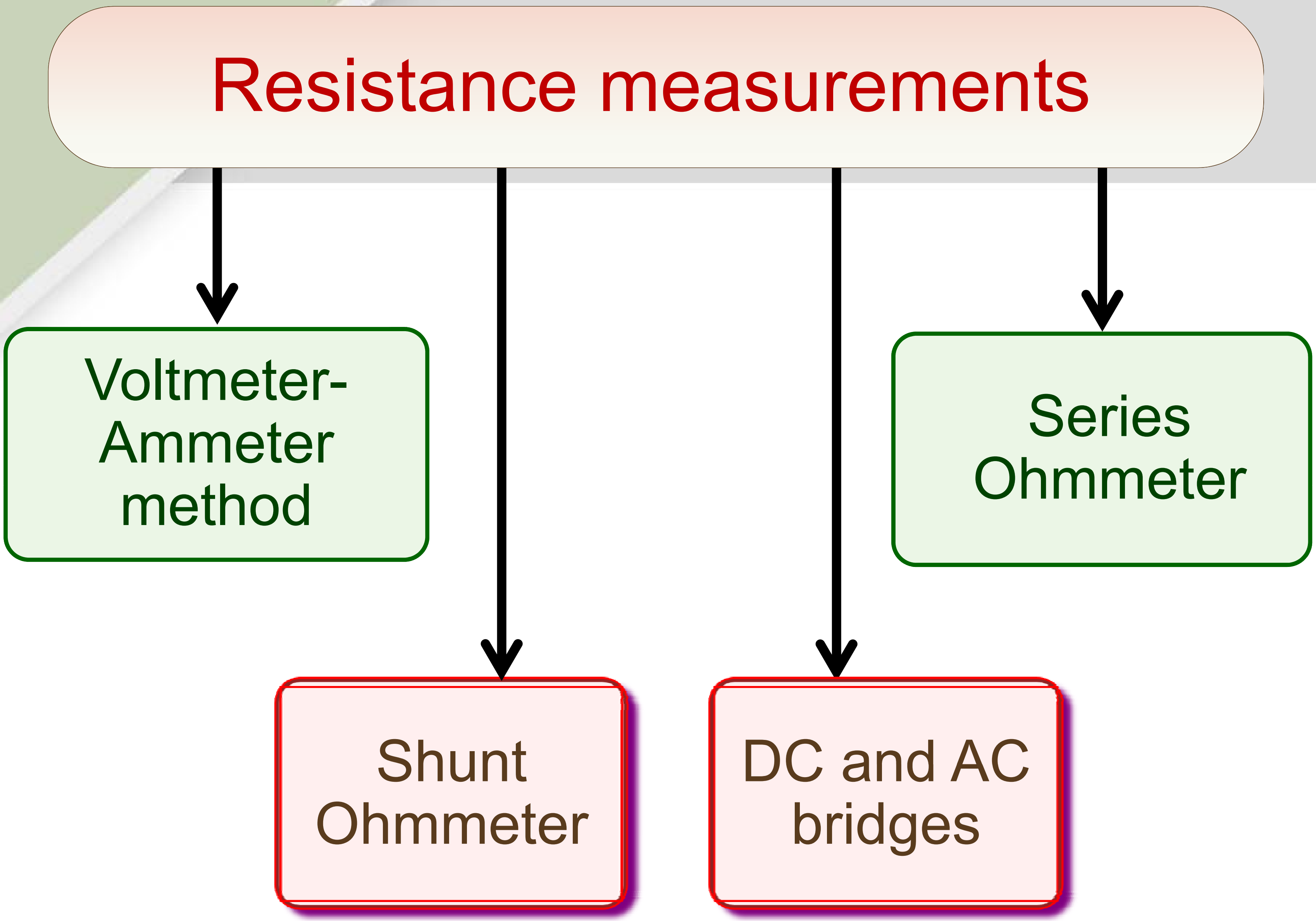

Resistance measurements
Voltmeter-Ammeter method
Shunt Ohmmeter
DC and AC bridges
Series Ohmmeter

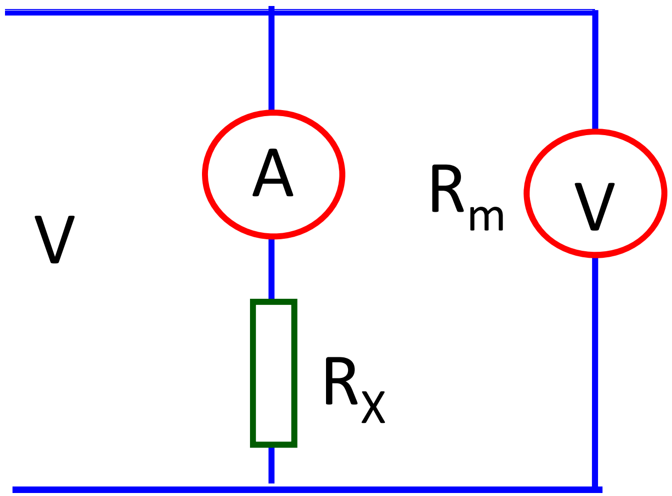
Resistance measurements

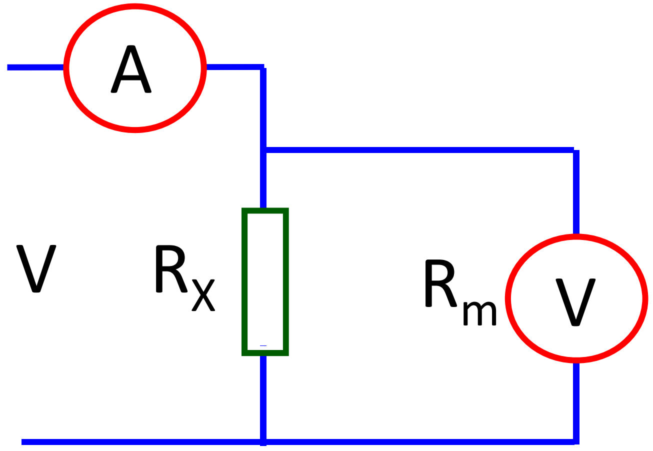
Voltmeter-Ammeter method

Simultaneous readings of the voltmeter and ammeter are required

The resistance is calculated from Ohm's law

$$R_X = \frac{V_m}{I_m}$$





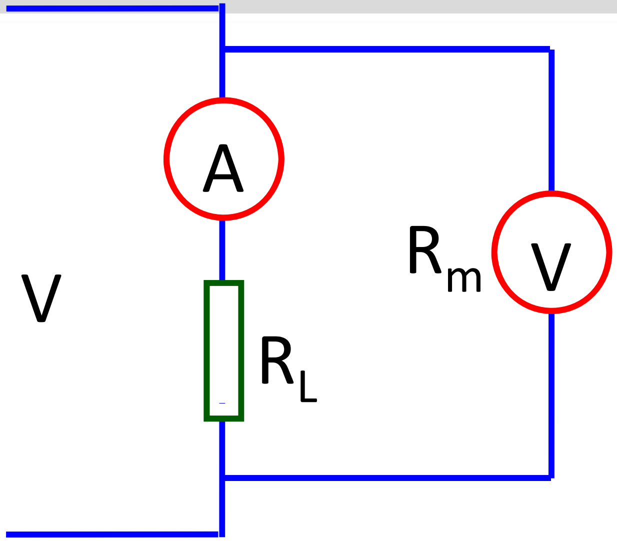
Resistance measurements

Voltmeter-Ammeter method

The ammeter reads the actual resistance current

The voltmeter reads the voltage across the resistance and the ammeter in series

This circuit can be used for small currents and large voltages



For large voltage and small current, the voltage drop across the ammeter will not affect the reading

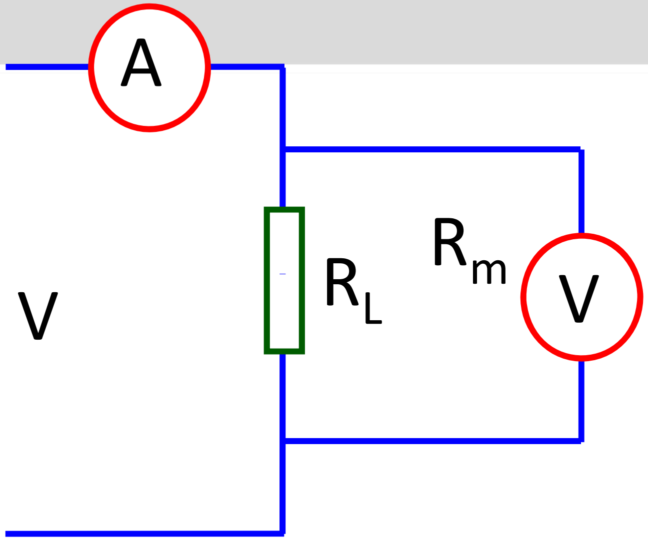
In other words, this circuit is suitable for high-resistance measurements.

Resistance measurements

Voltmeter-Ammeter method

The voltmeter reads the actual resistance voltage

The ammeter reads the current flowing in both the resistance and the voltmeter in parallel



This circuit can be used for large currents and small voltages

For large current and small voltage, the error in the current reading will be negligible

In other words, this circuit is suitable for low-resistance measurements

Resistance measurements

Series Ohmmeter

The ohmmeter measures the resistance placed between its leads

The resistance reading is indicated through a mechanical meter movement depending on electric current

The ohmmeter must have an internal source to create the necessary current to operate the movement

It must have appropriate **ranging resistors** to allow just the right amount of current through the movement at any given resistance

Resistance measurements

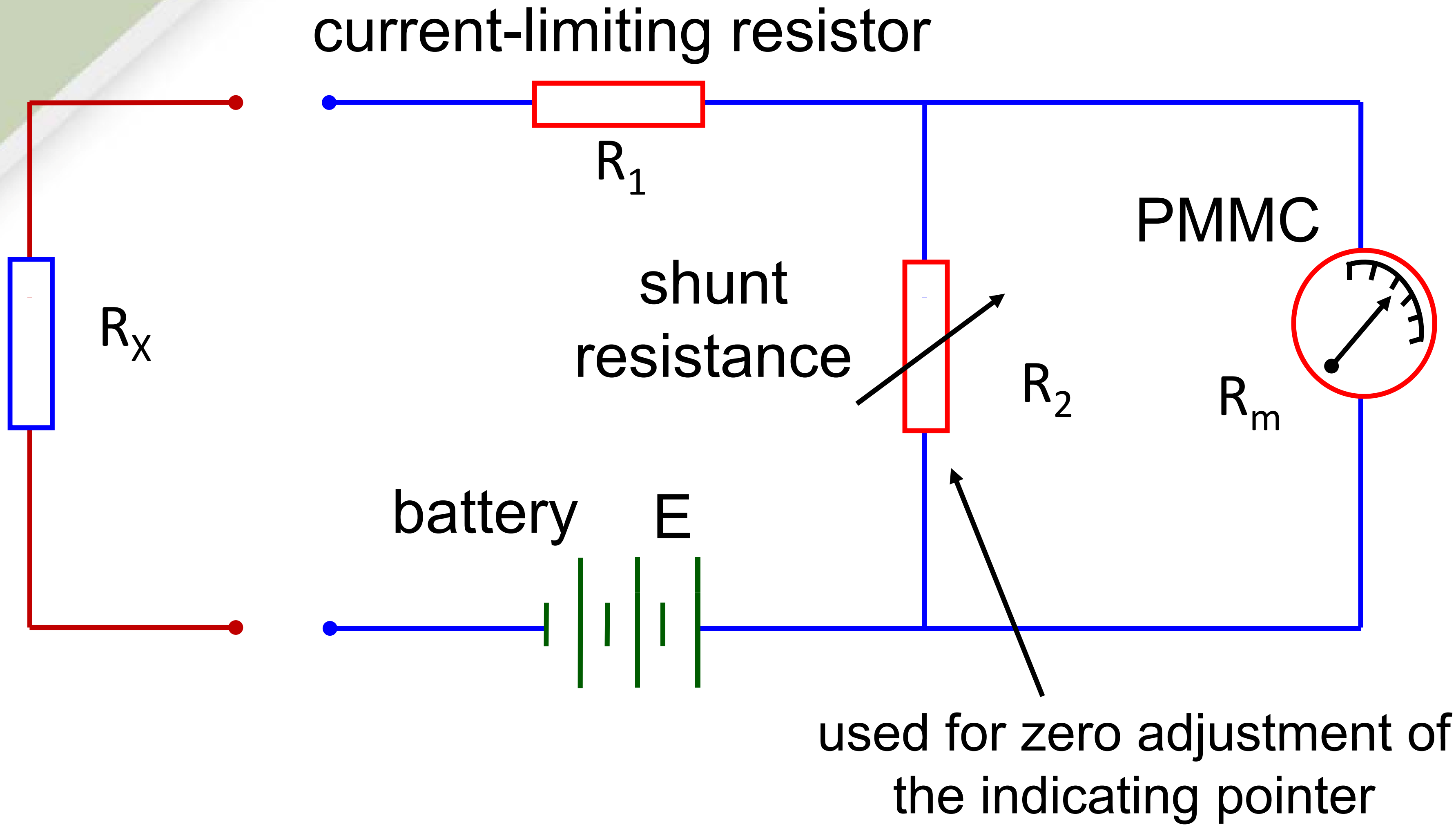
Series Ohmmeter

The deflecting torque produced due to the flowing current has the following characteristics:

- Proportional to the current flow
- Displayed on a back-off scale, with ohm values increasing to the left as the current backs off from full-scale deflection

Resistance measurements

Series Ohmmeter

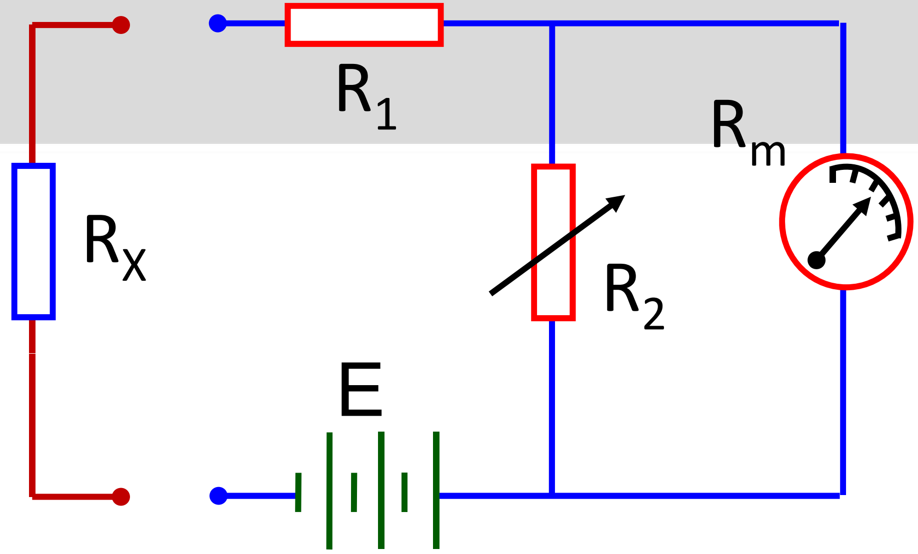


Resistance measurements

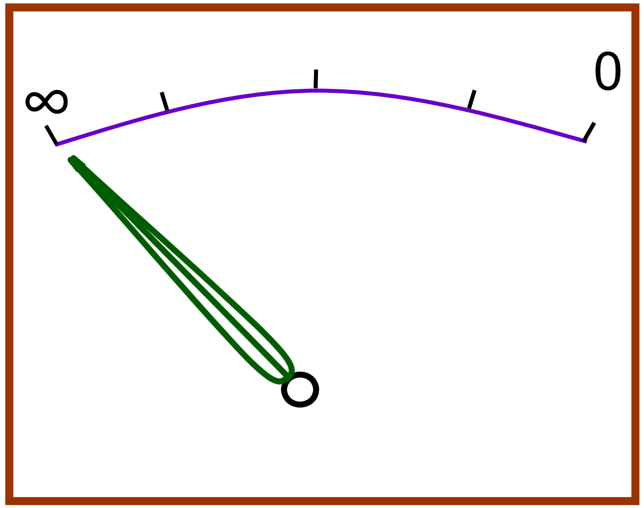
Series Ohmmeter

With open circuit:

- No current in the meter
- The pointer is to the left of scale

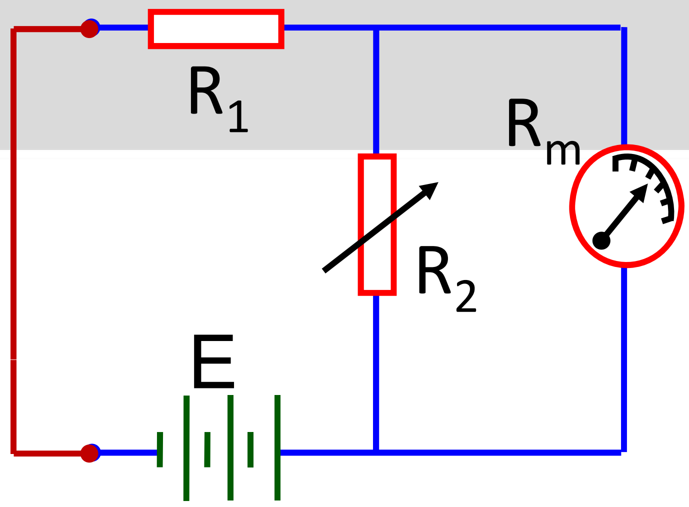


- The ohmmeter indication is "backwards" since voltage and current meters have zero at the left of scales



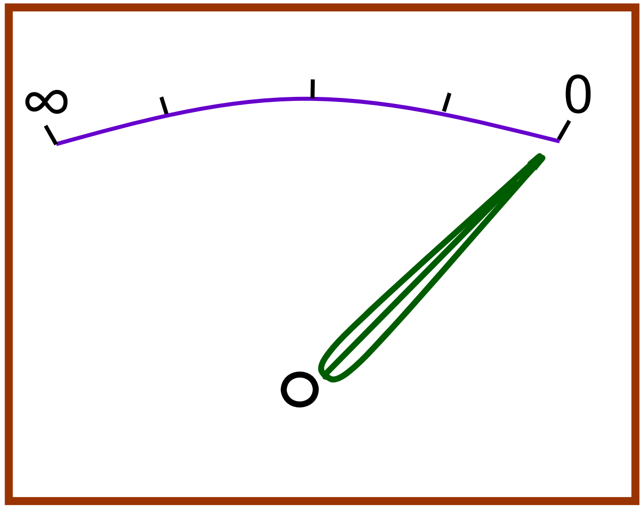
Resistance measurements

Series Ohmmeter



With short circuit:

- The meter current is maximum
- The current is limited only by the battery voltage and the internal resistance
- The pointer is to the right of the scale



Resistance measurements

Series Ohmmeter

Current in the meter depends on the unknown resistance

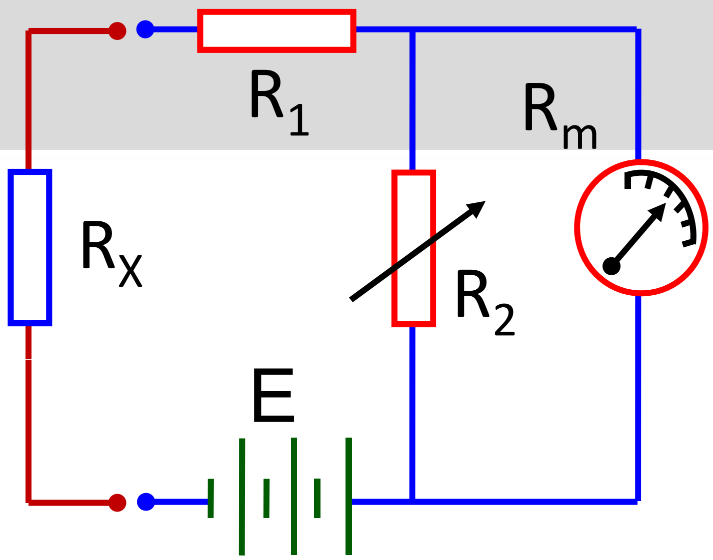
The meter deflection is non-linear

With law internal voltage, the current decreases and the meter will not get to zero indication “full-scale”

This process has certain limits and cannot be used in all cases

Resistance measurements

Design of series ohmmeter



R_1 and R_2 are obtained in terms of the "half of full scale deflection resistance"

It is the resistance that causes a half-scale deflection when connected across the terminals

Under the full-scale deflection conditions: $R_x = 0.0$

The equivalent resistance is

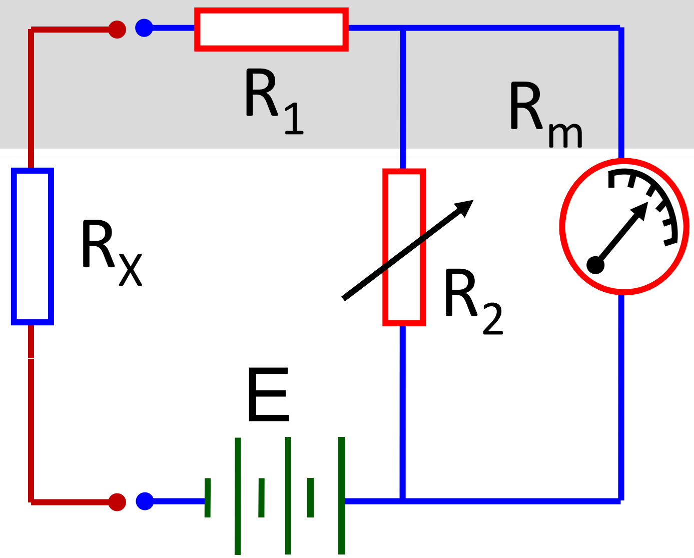
$$\boxed{R_{eq-fs} = R_1 + \frac{R_2 R_m}{R_2 + R_m}}$$

Resistance measurements

Design of series ohmmeter

The total resistance has to be doubled for half-scale deflection

The half of full scale deflection resistance is equal to the internal resistance of the ohmmeter



$$R_h = R_{eq-fs} = R_1 + (R_2 // R_m) = R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

"R_m" is the meter resistance

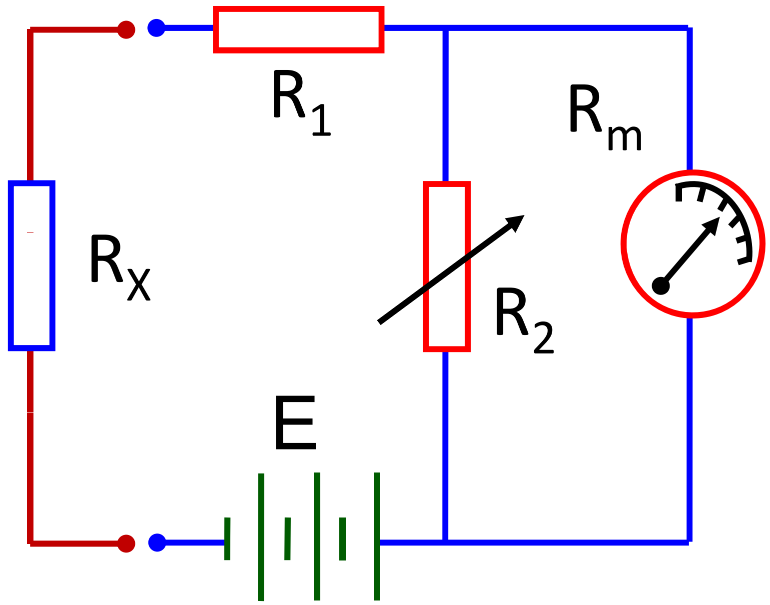
"R_h" is the half of full scale deflection resistance

Resistance measurements

Design of series ohmmeter

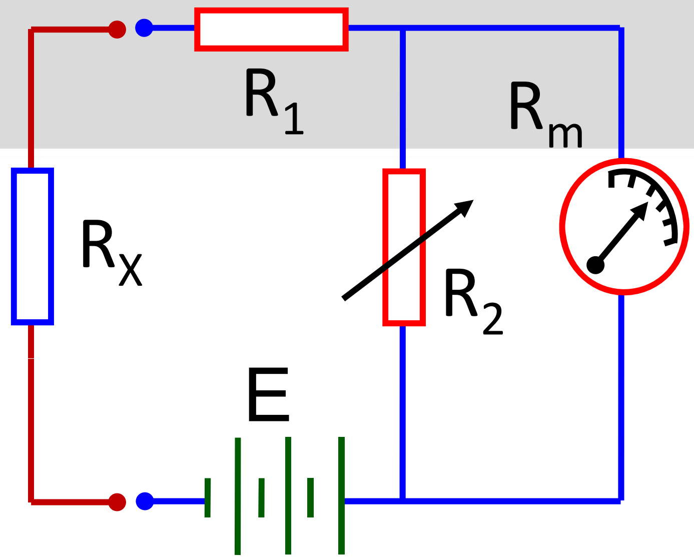
"R_1" and "R_2" are obtained according to:

- The full-scale deflection current "I_{fsd}"
- The meter resistance "R_m"
- The e.m.f of the battery "E"
- The half of full scale deflection resistance "R_h"



Resistance measurements

Design of series ohmmeter



The full-scale current is:

$$I_t = E / R_{eq\text{-}fs} = E / R_h$$

$$I_2 = I_t - I_{fsd}$$

$$V_{sh} = V_m$$

$$I_2 R_2 = I_{fsd} R_m \qquad \text{and} \qquad I_2 = I_t - I_{fsd}$$

$$\boxed{R_2 = \frac{I_{fsd} R_m}{I_t - I_{fsd}}}$$

Resistance measurements

Design of series ohmmeter

$$R_2 = \frac{I_{fsd} R_m}{I_t - I_{fsd}}$$

$I_t = E / R_h$

$$R_2 = \frac{I_{fsd} R_m}{\dfrac{E}{R_h} - I_{fsd}} = \frac{I_{fsd} R_m R_h}{E - I_{fsd} R_h}$$

$$R_h = R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

$$R_1 = R_h - \frac{R_m}{1 + R_m / R_2}$$

$$R_1 = R_h - \frac{R_m}{1 + \dfrac{R_m \left(E - I_{fsd} R_h\right)}{I_{fsd} R_m R_h}} = R_h - \frac{I_{fsd} R_m R_h}{I_{fsd} R_h + \left(E - I_{fsd} R_h\right)}$$

$$R_1 = R_h - \frac{I_{fsd} R_h R_m}{E}$$

Resistance measurements

Example:

A 100Ω basic movement is to be used as an ohmmeter requiring a full scale deflection of 1mA and internal battery voltage of 3V. A half scale deflection marking of 2kΩ is desired. Calculate the values of R_1 and R_2

Resistance measurements

Solution:

$$R_1 = R_h - \frac{I_{fsd} R_h R_m}{E} = 2000 - \frac{0.001 * 2000 * 100}{3}$$

R_1 = 1933.33 Ω

$$R_2 = \frac{I_{fsd} R_m R_h}{E - I_{fsd} R_h} = \frac{0.001 * 100 * 2000}{3 - 0.001 * 2000}$$

R_2 = 200 Ω

Resistance measurements

Shunt Ohmmeter

The resistance to be measured is in parallel with the meter movement of the ohmmeter

Used for measuring very low values of resistances

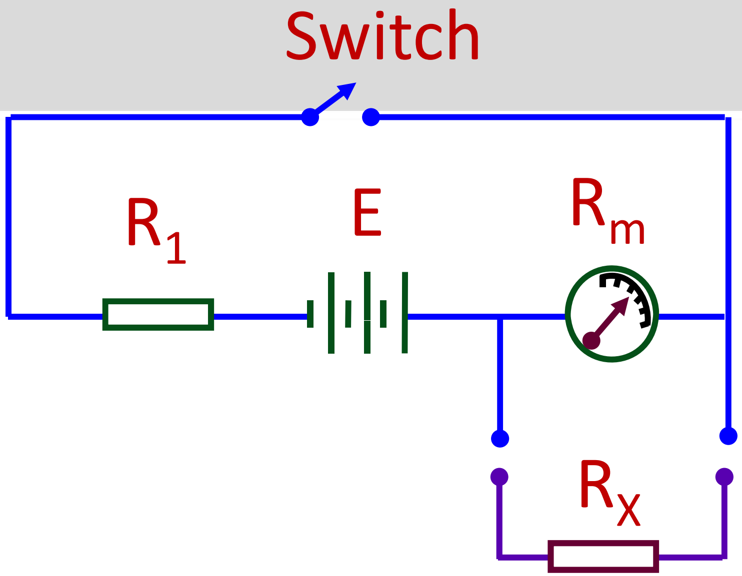
Firstly, voltage across the meter is adjusted until the meter pointer deflects full scale

Then, the unknown resistor is connected in parallel with the meter

The unknown resistance is indicated by the decrease in the current flowing through the meter

Resistance measurements

Shunt Ohmmeter



A battery and variable resistor in series are connected across a milliammeter

The resistor is adjusted until the meter reads full scale with the test terminals unconnected

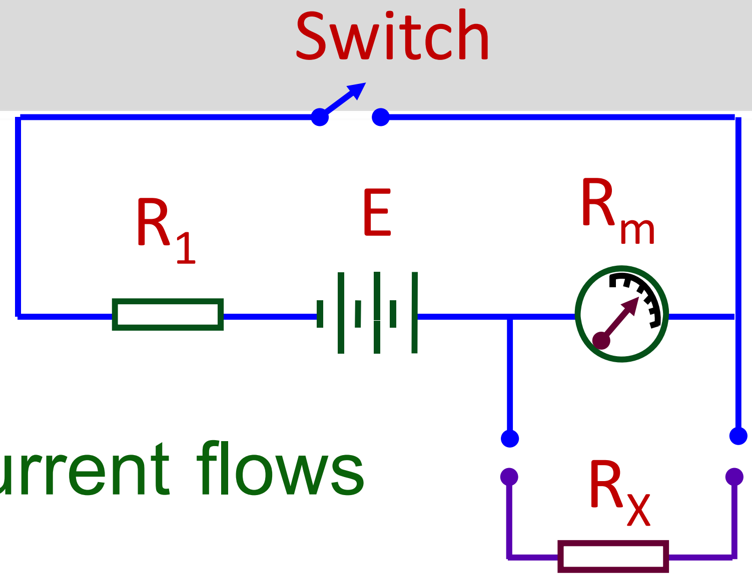
The external resistor will bypass some current and the meter reading will fall

The switch is used prevent the continuous current flow from the battery without external resistances

Resistance measurements

Shunt Ohmmeter

At short circuit: no current will flow in the meter and the pointer will not move



At open circuit: A maximum current flows in the meter

The resistance "R_1" is adjusted such that the flowing current causes a full-scale deflection at open circuit

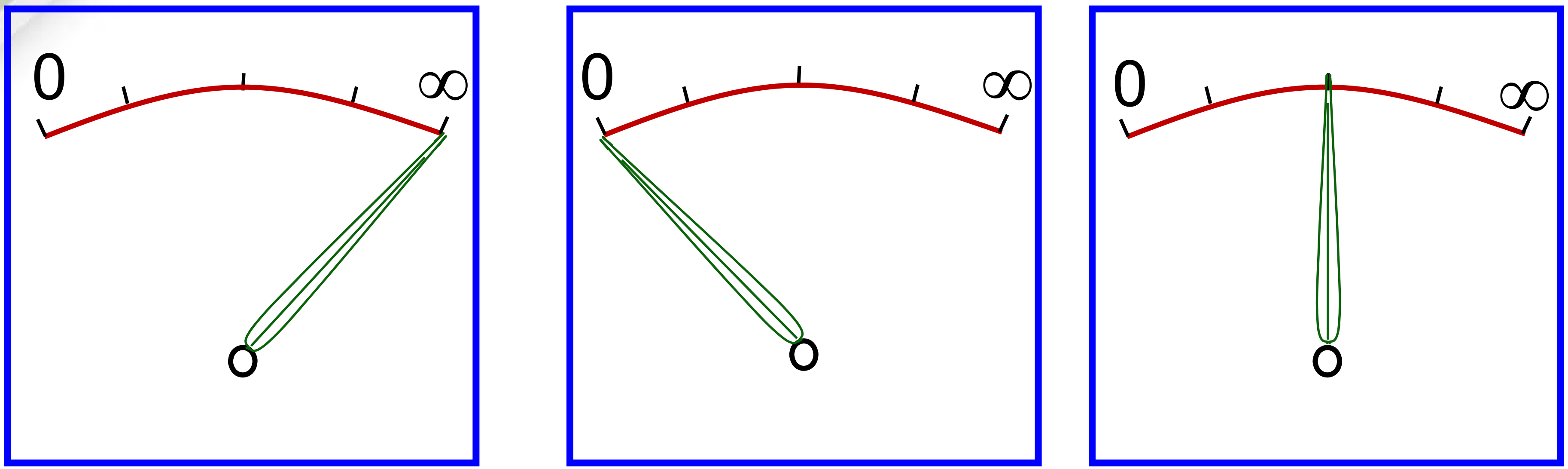
The scale of shunt ohmmeter is not reversed

The deflecting angle is in proportional to the connected resistance

Resistance measurements

Shunt Ohmmeter

The meter has a linear scale



open circuit (full-scale position)

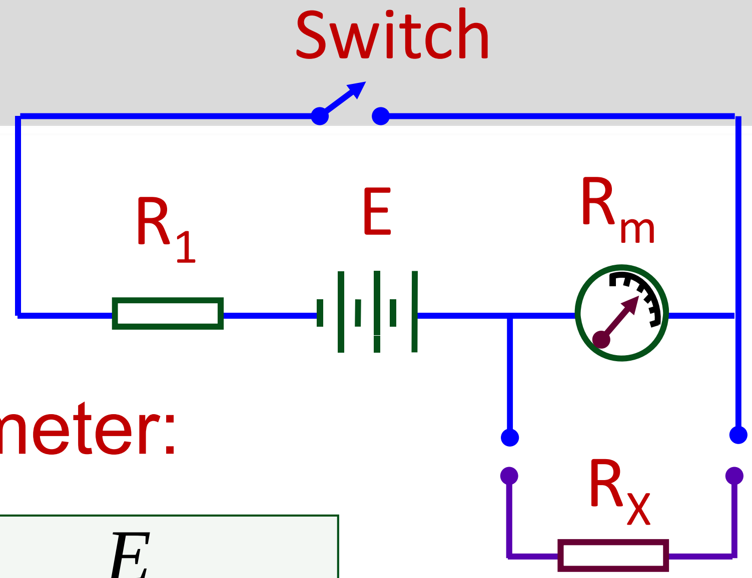
short circuit (reset position)

resistance connection

Resistance measurements

Shunt Ohmmeter

$$I_{fs} = \frac{E}{R_1 + R_m} \Rightarrow R_1 = \frac{E}{I_{fs}} - R_m$$



With "R_x" connected across the meter:

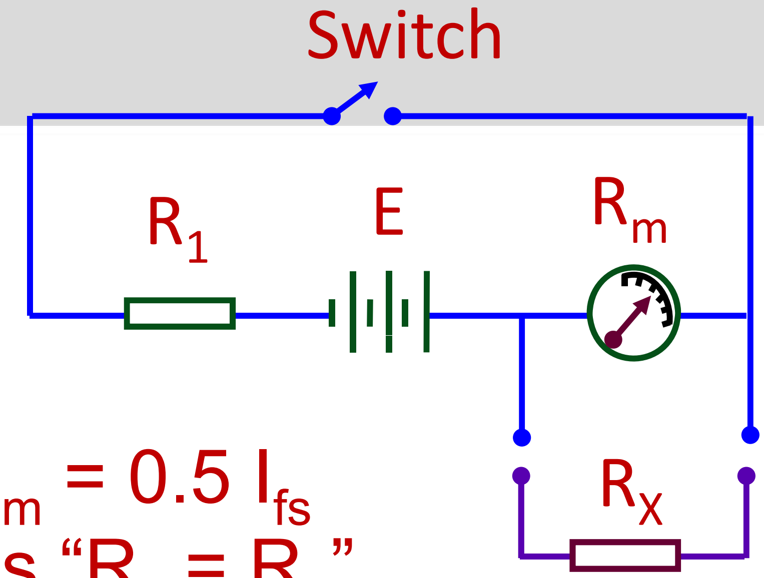
$$I_t = \frac{E}{R_1 + R_m // R_x} = \frac{E}{R_1 + \frac{R_m R_x}{R_m + R_x}}$$

$$I_m = \frac{E}{R_1 + \frac{R_m R_x}{R_m + R_x}} \text{ x } \frac{R_x}{R_m + R_x} = \frac{E \cdot R_x}{R_1 R_m + R_1 R_x + R_m R_x}$$

Resistance measurements

Shunt Ohmmeter

$$I_m = \frac{E \cdot R_x}{R_1 R_m + R_x\left(R_1 + R_m\right)}$$



The half-scale meter current is: $I_m = 0.5\ I_{fs}$
Half-scale resistance deflection is "$R_x = R_h$"

$$0.5 I_{fs} = \frac{E \cdot R_h}{R_1 R_m + R_h\left(R_1 + R_m\right)}$$

$$I_{fs} = \frac{2E \cdot R_h}{R_1 R_m + R_h\left(R_1 + R_m\right)}$$

Resistance measurements

Shunt Ohmmeter

$$S = \frac{I_m}{I_{fs}} = \frac{E \cdot R_x}{R_1 R_m + R_x (R_1 + R_m)} \frac{R_1 R_m + R_h (R_1 + R_m)}{2E \cdot R_h}$$

$$R_h = \frac{R_1 R_m}{R_1 + R_m} \Rightarrow S = \frac{R_x}{R_1 R_m + R_x (R_1 + R_m)} \text{x} \frac{\frac{R_1 R_m}{R_h} + (R_1 + R_m)}{2}$$

$$S = \frac{R_x}{R_1 R_m + R_x (R_1 + R_m)} \text{x} \frac{2(R_1 + R_m)}{2} = \frac{R_x (R_1 + R_m)}{R_1 R_m + R_x (R_1 + R_m)}$$

$R_1 >> R_m$ $\Rightarrow$ $$S = \frac{I_m}{I_{fs}} = \frac{R_x R_1}{R_1 R_m + R_x R_1} = \frac{R_x}{R_m + R_x}$$